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Predictive Modeling of Cultural Resources in the Theban Necropolis, Luxor, Egypt

Abstract: The Egyptian Government created the Egyptian Antiquities Information System (EAIS) and a Comprehensive Development Plan to help protect cultural resources in the Theban Necropolis, Luxor, Egypt. By creating a cognitive predictive model and assessing its utility in locating tombs, researchers could be aided in the understanding of why these locations were preferred by the ancient Egyptians. The cognitive evaluations used include tomb location relative to geology, slope, elevation, fractures, and religious/burial practices. A set of sensitivity surfaces was created using Geographical Information System (GIS) / statistical analysis of measured and derived environmental and cultural attributes. Analysis of fifteen sensitivity surfaces produced two viable models which could be combined with the EAIS database to help show which areas should be avoided or studied further. The most important information generated from this research is the fact that there is a lack of focus in the archaeological world concerning why tomb locations were chosen.

Introduction

The ancient capital of Thebes is located in present day Luxor, Egypt, 600 km south of Cairo in Upper Egypt at the great bend of the Nile and is a United Nations World Heritage Site (Strudwick / Strudwick 1999, 1–25). In the last thirty years metropolitan growth on the west bank of the Nile in the Theban Necropolis has expanded exponentially.

In response to the rapid growth, an executive study for the Comprehensive Development Plan for the City of Luxor, Egypt, was completed for the Ministry of Housing, Utilities and Urban Communities, Egypt (Abraham / Bakr / Lane 1999, 10–13). This plan proposes to integrate the growing city of Luxor and the ancient monuments of Thebes into a more environmental and tourist friendly city. One of the key problems with site management and preservation in Egypt is that the sites are not systematically located on official maps or collected into a database (Egyptian Antiquities Information System 2004). As a result, the Egyptian Antiquities Information System (EAIS) was established in June 2000 to create a bilingual Geographic Information System (GIS) for the management of historical sites in Egypt (Egyptian Antiquities Information System 2004). It was created as a part of the Supreme Council of Antiquities (SCA), with technical assistance from the Finnish Ministry for Foreign Affairs. This database will be used to integrate land use planning and decision making activities, thereby increasing historical site protection.

In order to help Egyptian Authorities locate unidentified cultural resources, tombs specifically, a cognitive predictive model was created. This type of predictive model was used because it relies on deductions from archaeological theory concerning past lifestyles instead of a correlative model which is more dependant upon the known archaeological record (van Leusen et al. 2003, 25–92; Whitley 2003, 123–138). Anthropological and historical literature of a region is examined in order to hypothesize which factors were important to a culture or group in the region. These variables are then used to define other areas with similar features, therefore predicting site locations (Hudak et al. 1995). Inclusion of this predictive model into the EAIS database would be useful in management and preservation planning while providing insight into the ancient Egyptian tomb location preferences. By identifying areas of high potential for sites, the planning commission will know which areas to avoid or to study further.

Methodology

The Theban Necropolis covers a large area west of the city of Luxor. Due to its large size, only a small portion was used for this study *(Fig. 1)*, because of data constraints and limited British Survey and geologic maps. With additional data, the model could be applied to the whole of the region. Egyptian tombs were the only type of cultural resource analyzed in this model. By only using tomb locations we were

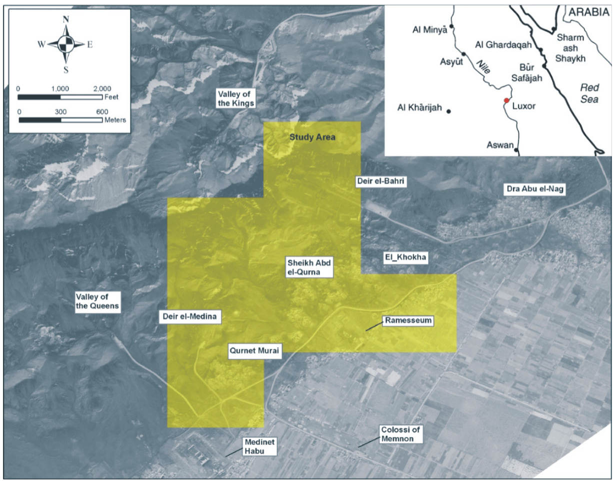

Fig. 1. Location of the study area (inset Perry 2004, p. 2).

able to focus on a smaller area while creating a more in-depth study which could be expanded to include other cultural resources in the future.

The model was created by analyzing both anthropogenic and environmental factors which may have had an impact on how tomb locations were chosen. Each factor was subdivided into at least one hypothesis indicating why the factors could have been useful in deciding tomb locations. These hypotheses were weighted and combined to create formulas. Only one hypothesis from each factor was considered in a formula. Once created, the formulas were used to generate predictive model sensitivity surfaces and tested to determine which was the most useful.

Factors

Six factors were selected in the creation of the formulas for the predictive model: geology, elevation, slope, orientation, fractures, and temple locations. Each was examined in detail and multiple hypotheses were created for each. The factors were assigned a value ranging from –1 to 1 for each hypothesis. These values were based upon their attributes as they applied to the cultural importance of the location of tombs. A value of –1 means that the expression of the hypothesis should correlate negatively with tombs, while a value of 1 means that the expression of the hypothesis should correlate positively with tombs. All other values range between the two, with 0 being the medium, no preference for or against tomb locations. Once the values were assigned, GIS analyses were run to create individual grids based upon each of the loadings and theories.

Geology

The geology layer was digitized from detailed field maps, based upon modern aerials, created by FRONABARGER (2006). Since no information could be found connecting geology to tomb locations, we analyzed the GIS layer and created two different hypotheses based upon rock types. The first hypothesis (ease of cut is good/stability is bad) assumes that Egyptian tomb builders would look for the softest rock type, which would allow tombs to be cut into the rock easily; saving time and labor. The reasoning behind this thought is that the easier it was to construct the tombs, the more efficiently the work could be done. The second hypothesis (stability is good/ease of cut is bad) assumes that the Egyptians would look for the hardest rock type, because it would provide more stable and long lasting tombs.

Two different sets of values were assigned to each rock type based upon the above hypotheses. As the Nile Floodplain is not a stable environment due to its make up of loose soil derived from silt and flashflood runoff, it is given a value of –1 for each of the hypotheses. The Tarawan Formation is considered a compact unit which was formed in a stable environment. Due to its ability to resist weathering and erosion, it is assigned a value of .85 for stability and –.5 for ease of cut. As shale is not known for its strength or cohesion but for its ability to be easily dug, the Esna Formation is assigned a stability value of –.5 and an ease of cut value of .5. The Thebes Group is assigned a value of .75 for stability due to the strength and durability of the limestone. It is assigned a value of –.2 for ease of cut due to the chert nodules which can reach boulder size. As the Conglomerate is poorly lithified, easily weathered, and consists of cobbles and boulders, it is assigned a value of –.75 for both stability and ease of cut.

The two alluvium deposits, Wadi and Outwash Plain, are assigned a value of 0 for both hypotheses because it is not possible to determine which rock types they overlay. The Scree deposits are assigned a value of .75 for both because they can indicate tomb building activity in the general area and can also be covering preferred geological layers. The Scree and the Esna Formation interface receives a value of .25 for both hypotheses, because it is a compilation of two rock types with scree slightly outweighing the value of the shale. Temple locations receive a score of 0 for both because, like the alluvium deposits, it can sometimes be difficult to distinguish the underlying geology. Modern houses are assigned a score of .75 for each hypothesis, because it is a well known fact that houses were sometimes built on the locations of tombs because the tombs could be used as cellars, bathrooms or other rooms in the house.

Elevation

The GIS elevation layer with a contour interval of two meters was digitized from the 1920s British Survey Maps and converted into a digital elevation model. Since no information could be found connecting elevation to tomb locations, we analyzed the GIS layer to create three different hypotheses based upon the range of elevation. The first (low elevation is good/high elevation is bad) assumes that the reigning Egyptians would have picked lower elevations because it was easier to reach and transport items to the tomb. The second (high elevation is good/low elevation is bad) assumes that they would have desired higher elevations because it would ensure tomb safety, provide lofty status, and a clear view of the temples and the blessed east. The last hypothesis (middle elevation is good/low and high elevation are bad) is that they would look for middle elevations because it would provide some safety from tomb raiders, moderate ease of access for the builders, and it would give the resident a lofty position in which to spend eternity (a good compromise).

Three different sets of values were assigned to the elevation surface based upon the above hypotheses. The elevation in the study area ranges from 80 m to 350 m. For the low elevation is good hypothesis, a value of 1 was applied to 80 m decreasing equally to a –1 at 350 m. The high elevation is good hypothesis received a value of 1 for 350 m decreasing equally to a –1 at 80 m. The middle elevation is good hypothesis received a value of 1 for 120 decreasing equally to –1 at 80 m and 350 m.

Slope

The GIS slope layer was derived from the digital elevation model in ArcGIS 9.1. Since little information could be found connecting slope to tomb locations, we analyzed the GIS layer to create three different hypotheses based upon the range of slope. Three hypotheses were considered when determining ideal slope for tomb locations. The first (steep slope is good/level slope is bad) assumes that a steeper slope will provide protection by limiting access to looters and provide an easy way to dispose of scree. Manniche (1987, 44–53) states that tombs located in low slope areas are prone to destruction and being covered up with sand. This would also suggest steeper slopes are more preferable. The second (moderate slope is good/level and steep slope is bad) hypothesis is that a moderate slope would be ideal because it would provide some protection from looters, moderately easy disposal of scree, and fairly easy access by the builders. The third (level slope is good/steep slope is bad) assumes that a low slope would provide easy access to the tomb builders making the tomb easier to complete.

Three different sets of values were assigned to the slope surface based upon the above hypotheses. The slope in the study area ranges from 0° to 90°. All the values assigned for each of the three hypotheses are a gradation of positive numbers. In the hypothesis steep slope is good, 90° slope is assigned a value of 1 and 0° slope is assigned a value of 0. The moderate slope is good hypothesis has a value of 1 assigned to 45° slope with a gradation down to 0 for both 0° and 90° slope. For the level slope is good hypothesis, 0° slope is assigned a value of 1 while 9° slope is assigned a value of 0.

Orientation

The Egyptian sun god was believed to cross the netherworld, which is located in the west, in order to be reborn in the east. This belief led the ancient Egyptians to orient their tombs from east to west, so that the tomb could pave the way to the "beautiful West" and help them be reborn into the afterlife (Halvorson 2003). As geological and topological features sometimes made this impossible, tombs can observe fictional directions (Hodel-Hoenes 2000). This orientation hypothesis was created as an aspect surface using elevation and cardinal directions to show which directions the topography actually faces. For the purpose of this study a value of 1 is assigned for due east and a –1 for due west with all other directions ranging between the two.

Fractures

A recent study, conducted by Parizek (2006) in the Theban Necropolis, claims that tombs can be pre-

Formula	Description	Formula	Description
A	.5 stability + .25 visibility is good + .25 east orientation	B	.5 moderate elevation is good + .25 stability + .25 high elevation is good
C	.5 low elevation is good + .25 ease of cut + .25 level slope is good	D	.5 stability + .5 fault presence is good
E	.5 temple visibility + .25 temple closeness + .25 east orientation	F	.5 stability + .5 fault presence is bad
G	.25 middle elevation is good + .25 stability + .25 moderate slope is good + .25 east orientation	H	.5 temple visibility + .5 temple proximity
I	.5 temple visibility + .5 east orientation is good	J	.5 stability + .5 east orientation
K	.2 middle elevation is good + .16 east orientation +.16 moderate slope is good +.16 stability + .16 temple visibility + .16 temple closeness	L	.5 stability + .25 fault presence is good + .25 low elevation is good
M	.5 middle elevation is good + .25 level slope is good + .25 fault presence is good	N	.25 middle elevation is good + .5 ease of cut + .25 east orientation
O	.5 steep slope is good + .25 stability + .25 middle elevation is good		

Tab. 1. Formulas and the description associated with each.

dicted based on the presence of fractures in the rocks. She claims that tombs can be located by finding fractures. This factor was added to the model to determine if fractures have predictive capabilities or if they are a pseudo-cause. There are two ways to weight fractures. The first hypothesis is that the Egyptians looked for fractures when building tombs, because it gave them an easy starting place. The second hypothesis is that the presence of fractures showed instability in the rock, and they would have stayed away from these locations at all costs. In the first hypothesis, a value of .75 was assigned to facture locations and –1 was applied to the second.

Temple Locations

Egyptian temples were considered microcosms of the world, the realm of the god on earth. They were holy places where people could be close to the gods and receive oracles (Nelson 1944, 44–53). While temples were created for gods, they were also seen as a monument to the king who commissioned the building (Halvorson 2003). As the nobles could not situate their tombs near the king, they would position them either adjacent to the temples or within a visible range. These monuments would many times inspire deviation from the usual east to west orientation (Hodel-Hoenes 2000).

Two hypotheses were used when determining which locations would be influenced by temple locations. The first is that Egyptians wanted to be as close to the temples as they could. A cost-distance surface was created based on temple locations and elevation to show which areas would require the least amount of effort to be reached and still be close to the temples. The second hypothesis is that Egyptians did not have to be close to the temples as long as the temples were visible from the tomb entrance. A visibility (line-of-site) analysis was run using elevation and temple locations to determine which areas would have a clear view of the temple.

Formulas

A total of fifteen formulas was created using combinations of the above mentioned hypotheses *(Tab. 1)*. There is little readily available research done in the area of tomb locations. These formulas were generated to broadly cover all hypotheses.

Only one hypothesis from each factor was used per formula. Each formula was derived by combining the hypothetical reasons that Egyptians might have used in deciding tomb locations. The hypotheses that are used in a formula are weighted depending on the importance of them in the scenario. Once the formulas were created they were inserted separately into the ArcGIS Spatial Analyst Raster Calculator to create 15 cumulative sensitivity surfaces representing the relative potential for all tomb locations within the Theban Necropolis.

Testing

A combination of the average predictive values and the observed/expected results were used in the assessment of the 15 different formulas (A–O). A database consisting of 406 known tomb locations was created using the 1920s British Survey maps, and two sets of more recent maps (Porter / Moss 1994; Kampp 1996). Relevant information, including tomb number, occupant name, dynasty, reigning king, and period was gathered (Porter / Moss 1994) and added to the database. These known tomb locations were used when calculating both average predictive and observed/expected values. The Hawthorne tools extension, a downloadable GIS script which extracts the corresponding model raster pixel for each tomb point, was used in ArcGIS to determine the predictive value for each tomb.

An average predictive value was first calculated by averaging the total predictive value for each tomb. It was computed for all the formulas, even those with tombs located in low potential areas. When these numbers are combined with the next test, any false senses of predictive capability will be revealed. Minitab was used to create histograms showing the quantity of tombs in each predictive value class. These were used to determine if there are any trends in the data.

In order to calculate the observed/expected values for the models, the initial values ranging from –1 to 1 were subdivided into eight new categories (i.e. $-1 \leq -.75 = 1$). The models and tomb locations were reclassified using these new numbers. The total and sum of the pixels were generated for each model in order to calculate the percentage of each new category. If the tombs were distributed randomly, then we would expect to see the same percentage of tombs scattered around in each group as the pixels in general. Using this assumption, it was possible to generate the number of expected tombs in each category.

Once the observed and expected number of tombs was generated, an observed – expected formula was used to create an unbiased assessment of the accuracy accounting for the precision distribution (i.e. what was observed given what was expected). This resulted in a range of positive or negative numbers for each category. The model with the most predictive capabilities would have more negative numbers in the lower categories and more positive numbers in the higher categories. This would show that the model has more tombs located in higher probability areas and fewer tombs located in low probability areas than was expected with the randomly generated locations.

Results

The average predictive value for all models ranged from –.56 to +.38, with models H, O, and M having the highest. When these values were compared to the observed–expected, one can see that these models are high, because no low probability area has been created. Out of the fifteen predictive models, only two models, A and J, showed both significantly high predictive ability (high average predictive values, .29 and .26, and a good spread for observed–expected), with A having slightly higher results. While J has good predictive capabilities, the addition of the temple visibility created a stronger model. This lends credibility to the belief that Egyptians preferred tombs facing the east, but when that was not possible, the tombs would face the temple of the reigning king. Both of these models lend credibility to the belief that Egyptians looked for stable rock when choosing locations for tombs. These models might be improved by creating formulas that weight the factors differently.

Seven of the models (A, D, F, J, M, N, and O) showed bimodal distribution which was easily seen in the histograms. Each model was checked to see if any patterns could be distinguished. This analysis showed no discernable difference between dynasty, reigning king, and period. There are many tombs located in the study areas for which this information is not known or was not available. If a more comprehensive database were to be created, it might reveal why these configurations occurred. There is no one common factor used in these models which might explain why this bimodal distribution occurs.

Model B was the only model that created reverse predictability. This model is not reliable as one or all of the factors involved might be reversed to create a model where all the tombs fall in high probability areas. On the other hand, this might create a model that contains no low probability areas at all, resulting in very low precision.

Models D and F resulted in exactly the same average predictive value and values for precision. This is very interesting, because the only difference between the two formulas was that D stated that the presence of fractures was good while F stated that the presence of fractures was bad. When examining the raw data, it is noted that fracture patterns in the tomb locations have not been sufficiently mapped. Thus, additional fracture mapping needs to be conducted.

Conclusions

The predictive model was able to produce two viable explanatory models, A and J. These models provide a good place to start the manipulation process in order to further examine the complexity of tomb location choice. These two models show that stable rock, an eastern orientation, and orientation facing Royal temples were important when choosing tomb locations. The models were not able to determine to what extent these factors were necessary or which was more highly desired. The factors of elevation, slope, and fractures do not appear to have been used to make the decisions. This does not mean that the Egyptians did not consider them when picking tomb locations, just that the explanation is still incomplete. New formulas can be created and tested to try to determine if other unidentified factors were important. Once these have been determined, they can be used to locate unknown tombs or tombs whose locations have been lost throughout the whole of the Theban Necropolis.

The most important information that can be gathered from these models is not necessarily which formula works best, but the fact that there is a lack of knowledge in the archaeological world as to why these locations were chosen. Most archaeological research has been limited to finding out about the person who was buried in the tombs, and not necessarily why the tomb is located it that specific spot. This is a whole side of Egyptian archaeology which has not been fully explored. If more focus is placed on this avenue, then better models can be created which can lead to the discovery of new tombs, and the complexities of cognitive decision making.

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